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ABSTRACT

This paper is concerned with a low cost alternative for providing computer experience to secondary school students. The brief discussion covers the programmable calculator and its relevance for teaching the concepts and the rudiments of computer programming and for computer problem solving. A list of twenty-five programming activities related to high school mathematics is included. (DAG)

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(An Alternative to the Cost of Large Computers)

J. Richard Dennis and David Thomson

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Low-Budget Computer Programming in Your School
(An Alternative to the Cost of Large Computers)

by

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If given a choice between a computer, selling for several thousand dollars, complete with all the hardware, software, and qualified personnel to make it function properly, and a programmable desk calculator, selling at most for a few hundred dollars, complete with a cassette recorder, perhaps an adding machine type printer, and some sample programs, which would you choose? This is a difficult question to answer. It is a lot like asking whether one is better off earning \$50 a week when hamburger sells for 25¢ per pound or earning \$150 per week when hamburger sells for 89¢ per pound. Many complicated elements figure into the answer to such questions. This paper is concerned with a low cost alternative for providing computer experiences to secondary students. We shall discuss the programmable calculator and its relevance for teaching the concepts and rudiments of computer programming and for computer problem solving activity. Our remarks deliberately have been kept non-technical on the belief that we primarily would be addressing an audience not already knowledgeable of computers.

The first question to answer when considering purchase of computing equipment is "What precisely, do you intend to do?" Then before buying any equipment you should thoroughly investigate its capabilities, from the viewpoint of possible classroom uses, to determine the extent to which such activity matches your desires and curriculum goals. In a later section of this paper we will illustrate some of the mathematics activities that are amenable to a programmable desk calculator. But as a general rule, you will find that computing devices usually are limited mostly by your own ingenuity and the time you are willing to invest in doing a particular task. Also, for teaching the rudiments of computer programming, many of the programmable devices provide opportunities to learn and to apply the important concepts and operations of the subject.

One important feature a programmable device should have is the ability to save your work (programs and/or data) from session to session. Some programmable calculators do this with a simple cassette recorder. Others have magnetic strips for this purpose. Some of the cassette models have the advantage of operating (reading from or writing onto the tape) under the control of your computer program. This makes a set of interconnected small programs appear to be a very large program, even though the size of a single program is limited to a couple of hundred operations or steps. In computers, program length may be a few to many thousand steps, and the single steps usually are more sophisticated. Program storage for computers is via decks of cards or paper tapes which are virtually boundless, or by large capacity magnetic disks or tapes capable of storing large numbers of programs or amounts of data.

But again, one can view these differences as only a test of personal ingenuity and/or patience. Most large computing jobs can be broken into a series of self-contained small jobs. The ingenuity is required to make each piece work and all pieces to fit together into the whole desired. The patience is required in the greater amount of time to accomplish the whole task.

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For a large computer, specialized personnel or training may be required for operation. This increases the expense of the computer facility; and the larger the facility, the more people required to keep it running. The programmable desk calculator requires no specialized personnel to operate it. A teacher can usually pick up the procedure for using one from the manual that accompanies the machine. The manual usually explains some special functions of the machine, sample programs, and helpful suggestions for best use.

Computers usually are capable of communicating both in numerical and in literal (letters/words) information. The computer itself doesn't do this. Rather, the computer has a capacity large enough to house other programs to bridge or translate between exclusively numerical operation and mixed numerical, literal styles. This is not the case with programmable calculators, which normally work only with numerical data. This changes the type of interaction that may take place between the machine and the user. In a computer, programs may be written so that instructions are supplied to the user when data or other response by the user is required. And results may be output accompanied by descriptive words and sentences to explain their meaning. On a programmable calculator programs need to be accompanied by direction sheets so that the student knows when to provide the various inputs to obtain the desired outcomes. And output is either in exclusively numerical form, or can be tagged by a single alphabet character. In the later case the student needs a list to tell what each letter denotes in the particular program. For programs written by students, they need to keep a record of such information about the program for use by others.

One of the features that makes the programmable desk calculator attractive is its portability. It is small enough and light enough to be carried into any classroom and used on a desk top. This "go anywhere" capability is especially convenient if different classes are to use the same machine. No time consuming rescheduling of rooms need occur. Also, there is no special installation of environment control required which can be very costly. No special room need be set aside exclusively for computer activity. The battery operated models may be taken on field trips, to process data as it is collected.

To facilitate the teaching of programming, computing equipment should provide students with the following programming experiences or capabilities:

1. Inputing and outputing data--providing information to a program, and securing results from a program. It should be possible to do this within programs as well as before and after.
2. Calculation and variables--storing numerical information, performing sequences of calculations on this information, ordering operations, recalling stored information.
3. Conditional (or unconditional) branching--testing for specified conditions and being able to alter action based on truth/falsity of those conditions. This capability makes iteration possible.
4. Subroutines--a given set of operations may be needed several times in a particular program. A subroutine is a mini-program involving that set of operations. Each time they are needed, the program branches to the subroutine does the set of operations, and returns to continue the main program. This saves program space because the set of operations need be written only once. To do this the computing devices must be able both to branch according to several numerical conditions and to put labels on program steps.

The following features in programmable devices assist in locating and correcting errors in programs (a process called debugging the program).

1. Stepping capability--permits execution of a program one step at a time to see results after each single operation.
2. Editing operations--permits insertion/deletion of operations or steps in a program without rewriting all of the program.

From extended experiences in both advanced high school mathematics classes and remedial junior high school arithmetic classes, the following list of programming activities has been prepared. All activities can be done with a programmable calculator. The list is arranged in no particular order, and is by no means exhaustive:

1. Measurement conversion from one type of units to another.
2. For a given principle, rate, and number of years, calculate compound interest for each intermediate year.
3. Convert number of quarters, dimes, and nickles to dollar value.
4. Evaluate or solve equations of various types.
5. Check arithmetic practice.
6. Input a number and test for primeness.
7. Calculate distance traveled by a projectile, given muzzle velocity and initial angle of inclination.
8. Do payroll calculations (either simple ones involving fixed income rates and deductions or more complex ones with variable income rates graduated tax rates).
9. Solve systems of equations.
10. Approximate nth roots of numbers.
11. Sum sequences/series to specified number of terms.
12. Input coordinates of various standard polygons, output perimeter or area.
13. For a hollow sphere, input interior and exterior dimensions and output volume.
14. Convert among rectangular, spherical and/or polar coordinates.
15. Program computer to permit student to play a variety of number guessing games.
16. Calculate function values for graphing more complicated functions.

17. Input latitude and longitude of two locations, output great circle distance between them.
18. Input coordinates of three points, test for collinearity.
19. Input coordinates of two points on each of two lines, output coordinates of intersection, or test for parallels/perpendiculars.
20. Programs to translate messages to/from a variety of codes (see The Code Breakers, by David Kahn, New York: The Macmillan Co., 1967).
21. Calculate Fibonacci numbers.
22. Solve for missing parts of a triangle.
23. Studying convergence of (nontrivial) functions and series.
24. Approximate areas under various curves.
25. Approximate integrals by doing Reimann Sums.

Many other applications are possible in mathematics, science, social science, and business classes. The teaching of many of these concepts can be significantly enhanced by programmable devices of even the simple variety considered here. There are many other sources of activity ideas such as Creating Computing which is published several times yearly (Box 789-M, Morristown, New Jersey), and various publications of the People's Computer Company (Box 310, Menlo Park, California). And, most suppliers of calculators and computers offer materials suggesting a variety of uses for their equipment.